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A. F. BLOSSEY AND E. J. BOLLES.

THE USE OF HYDROCARBON AS A FUEL IN AN INTERNAL COMBUSTION ENGINE.

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THE USE OF 'HYDROCARBON' AS A FUEL IN AN INTERNAL COMBUSTION ENGINE

by

ALBERT FREDRICK BLOSSEY ✓

A Thesis Submitted for the Degree of

BACHELOR OF SCIENCE

Mechanical Engineering Course

and

by

EDGAR JAMES BOLLES ✓

FOR THE DEGREE OF BACHELOR OF SCIENCE

Electrical Engineering Course

UNIVERSITY OF WISCONSIN

1905

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THE USE OF 'HYDROCARBON" AS A FUEL IN AN INTERNAL COMBUSTION ENGINE.

'Hydrocarbon' is a byproduct of Pintsch gas manufacture Being a mixture of oils of various specific gravities, its uses in the trades and the arts have been very limited. Though the supply is small, it still exceeds the demand, and the price is correspondingly low.

The idea of using 'Hydrocarbon' as a fuel for an internal combustion engine was conceived through an inspection of the LaClede gas works, St. Louis. It was learned that the oil had been experimented with in various ways, but, so far as could be ascertained, not in an oil engine.

Mr. W. A. Baehr, Engineer for the LaClede gas works, was conferred with upon the subject of this new use of 'Hydrocarbon'. He manifested his interest in the project by contributing a barrel of the oil for the test.

A kerosene oil engine was procured with which to carry on the experiments.

It was deemed desirable to use a brake that could be changed rapidly, or by small increments. For this purpose a dynamo was chosen, and was obtained through the kindness

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of the Electrical Department.

In making the following tests on 'Hydrocarbon', two distinct objects were held in view. The first of these was to determine the physical properties and the general behavior of the oil. And second to devise a means whereby the oil could be used advantageously as a fuel in an oil engine.

'HYDROCARBON'

'Hydrocarbon' is the commercial name given to a certain oil derived from Pintsch gas. Pintsch gas, as is well known, is used extensively for car lighting and as such is stored in tanks under a pressure of from 6 to 8 atmospheres. When this gas is compressed for storage the above oil condenses off. As a consequence its production is limited to Pintsch gas works and is not extensive.

As far as could be ascertained the uses to which this oil has been put are quite limited and not especially important. The fact that but a comparatively small amount of it has been produced has not made it a particularly inviting field for investigation. Its production is about one gallon per thousand cubic feet of compressed gas. Its commercial value is not fixed since it can hardly be classed as a marketable product. At LaClede gas works, Mo. it is

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sold in large quantities at wholesale at 5¢ per gallon. While for smaller quantities it sometimes sells for as much as 20¢ per gallon. At these works attempts are being made to reclaim, with 'Hydrocarbon', the sulphur deposited in the purifying boxes. At the time of our visit to these works in Sept. 1904, there had been no success in this line. Lunge gives its composition as mostly benzine and toluene together with certain percentages of benzine derivatives The difficulty of separating these latter from the benzine and toluene makes it impossible to use the oil for gas making, as would naturally suggest itself first. Lunge also states that it has been used in Belgium for varnish making, but to what extent is not known. 'Hydrocarbon' has been used around rubber works and has been distilled and the distillate used for vapor engines. Again it has been deodorized and made fragrant by the addition of a few chemicals, and is sometimes used in perfumery.

Upon receiving the barrel of 'Hydrocarbon' from Mr. Baehr we were cautioned as to its use and advised to keep at least 100 feet from any open fire. Naturally we proceeded with some fear and decided to first determine as far as possible its nature and behavior. When the barrel

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was first opened it was noted that the pressure of the gas within was considerable, the temperature of the oil being that of the out door air during the winter months. A flashing test showed results similar to that of gasoline. When placed in a burner designed for gasoline, it burned satisfactorily with a small bluish flame. When mixed with kerosene and placed in a kerosene burner it also burned much the same as in the gasoline burner. Its odor is peculiar to itself but it has traces of gasoline, kerosene, and other hydrocarbons in it. It evaporates readily when poured upon the hand leaving a strong cooling sensation.

In order to determine some of its chemical properties a fractional distillation test was made under the supervision of Dr. Patten of the University. For this purpose a distilling flask and Liebeck condenser were used. For driving off the lighter fractions the flask was placed in a hot water bath. Later this was replaced by an oil bath and finally exposed to the direct action of a Bunsen flame. The results of this test are given in the following table:

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Total Quantity in Flask, 500cc.

Limit of Temperatures	Amount distilled over	Per Cent
Up to 30°C	trace	----
30° - 56°	36 cc.	7.2
56° - 75°	60	12.0
75° - 85°	120	24.0
85° - 100°	123	24.6
100° - 120°	136	27.0
120° - 130°	16	3.2
Remainder	6	1.2
Lost	3	0.6
	500	100.00

These results show that over 75% passes over between 75° and 120°C. Also that there is enough passing over above and below these limits to give an oil of exceedingly complex nature. As before noted there is a certain small percentage of the oil whose vapor pressure is greater than atmospheric. This is evident from the fact that if a bottle of newly drawn 'Hydrocarbon' be corked up and allowed to stand for some time, there will be considerable of a "pop" upon an attempted removal of the cork. That there also is but a very small percentage is evident both from the above analy-

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sis and from the fact that the above phenomenon is not noticeable after the oil has been open to the air a short length of time. Another point worth noting is the small amount of heavy constituents present. There is no doubt but that this could have been vaporized by increasing the temperature a few degrees. Hutton and Robinson give tables of Petroleum distillates, with their distilling temperatures, parts of which are added here for comparison.

Name		Distilling Temperature Hutton C.	Robinson C.	Sp. Gr.
Gasoline		60°-70°	----	.636 - .657
Benzene Naptha	C	70°-120°	60°-100°	.680 - .700
"	B	----	80°-120°	.714 - .718
"	A	120°-174°	100°-130°	.725 - .737
Kerosene		170°-	----	.780 - .820

These tables do not conform very closely but it is safe to assume that a large percentage of 'Hydrocarbon' is Benzene Naptha C and B with small proportions both above and below this class. An Hydrometer test showed the specific gravity of the oil as a whole to be .703, which is in accordance with the conclusions above. The only discussion to be found upon 'Hydrocarbon' is given by Lunge who states that its

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composition is mostly Benzene and Toluene as before noted.

HEATING VALUE:- For various reasons it was important to know the heating value of 'Hydrocarbon'. Whether used in an oil engine or otherwise as a fuel its commercial value depended to a large extent on this knowledge. For this purpose a Junker's calorimeter was used. As stated heretofore it was found that the oil would burn readily in a gasoline burner such as used in connection with a Junker's calorimeter. The test was conducted exactly as in the case of gasoline. Three independent trials were made, two of which checked very closely and are given herewith. The following gives the data and results:

	Test No. 1	Test No. 2
Mean temperature incoming water °C	6.53	6.55
" " outgoing " "	33.03	37.03
Change in " of " "	26.5	30.48
Grams or cc. of water heated	4275.00	3745.00
Calories of heat produced	113300.00	114200.00
B. T. U. " " "	453.2	456.8
Grams of 'Hydrocarbon'burned	10.0	10.0
B. T. U. / lb. of oil	20600.00	20700.00

Mean of two tests 20650 B.T.U./lb. of 'Hydrocarbon'

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PROPORTION OF CARBON AND HYDROGEN:- In order to determine the percentage of carbon and hydrogen in the oil a method suggested by one of the instructors in the College of Engineering, was used. As is well known, in the use of a Junker's calorimeter the combustion of the hydrogen in the fuel with the oxygen supplied, forms water, which condenses and can be collected on the outside of the calorimeter. If the amount of this water, which is formed, is known when a certain amount of fuel is consumed, then the amount of hydrogen in that fuel can be determined. While the method does not represent a great degree of exactness, for the want of some better method, it served our purpose. The results obtained are as follows:

Grams of fuel burned - - - - - - - - - - - - - - - - 10

" " water produced - - - - - - - - - - - - - 14

" " hydrogen in this amount of water 1/9 x 14 = - - - - - - - - - - - - - - - - -1.555

Assuming that the fuel is composed entirely of carbon and hydrogen the remainder must be carbon or:

Grams of carbon = 10 - 1.555 = - - - - - - - 8.445

Percentage of hydrogen in fuel $\frac{1.555}{10}100 = 15.55$

" " carbon " " $\frac{8.445}{10}100 = 84.45$

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Assuming calorific value of

Carbon - - - - - - - - - - - -	14600	B.T.U.
Hydrogen - - - - - - - - - - -	62000	"

One lb. fuel should yield

14600 x .8445	=	12350	"	
62000 x .1555	=	9650	"	
Total		22000	"	

This is higher than that determined experimentally for obvious reasons. In the actual combustion of the fuel a certain amount of energy is required to tear the molecules apart and consequently the available heating value is diminished.

Conclusion. From the meagre information we had had previously concerning 'Hydrocarbon', we believed it to consist of a complex mixture of various hydrocarbons of which the heavier constituents played the most important part. The result of our investigations, however, did not coincide with our previous idea. We found an oil with a small range of vaporizing temperatures and the percentage of heavy hydrocarbons much less than expected.

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THE ENGINE.

SELECTION OF AN ENGINE:- The engine selected for our tests was a Mietz Weiss kerosene oil engine. Our reasons for such a choice were as follows:

As previously stated our original idea as to the composition of 'Hydrocarbon' led us to believe it would work satisfactorily in an engine designed for the heavier oils. The advantages of steam in the cylinder to prevent carbonization and the absence of electric igniter were points considered. We also desired to use an engine of the two-cycle type, and since nothing of this nature was in the University laboratory, several manufacturers were approached with a view of obtaining a loan. The matter was also laid before the officials of the College of Engineering, with the result that an engine was purchased and placed in the hands of the experimenters.

THE MIETZ WEISS ENGINE:- Though it is primarily the object of this thesis to determine whether 'Hydrocarbon' can be used as a fuel for an internal combustion engine, the engine chosen for the test also presented many interesting problems, as will be herein -after shown.

In order that the experiments may be better understood,

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a description of the engine will be given.

The principal features of the engine used are:

(1) Oils of a specific gravity of 80 and above can be used as a fuel.

(2) It is built on the two cycle plan with compression in crank chamber.

(3) Steam from the cooling water is used in the cylinder.

(4) No igniter in the form of electrical sparker, or a hot tube, is required.

During the compression stroke in the head end a partial vacuum is formed in the closed crank chamber, 20 Fig.1. As the suction port, 19, is uncovered by the piston, air rushes in, being supplied through the lower air ports, 18, 19. When the piston moves forward the inlet port is again closed, and the air is compressed in the crank space.

Near the forward end of the stroke the exhaust and inlet ports, 30, 22, are uncovered almost simultaneously. The compressed air from the crank space is forced through the air port, 21, 27, 22, into the combustion space, 16.

The method of cooling the cylinder is very novel. The water does not fill the water jacket, 23, but is kept at a

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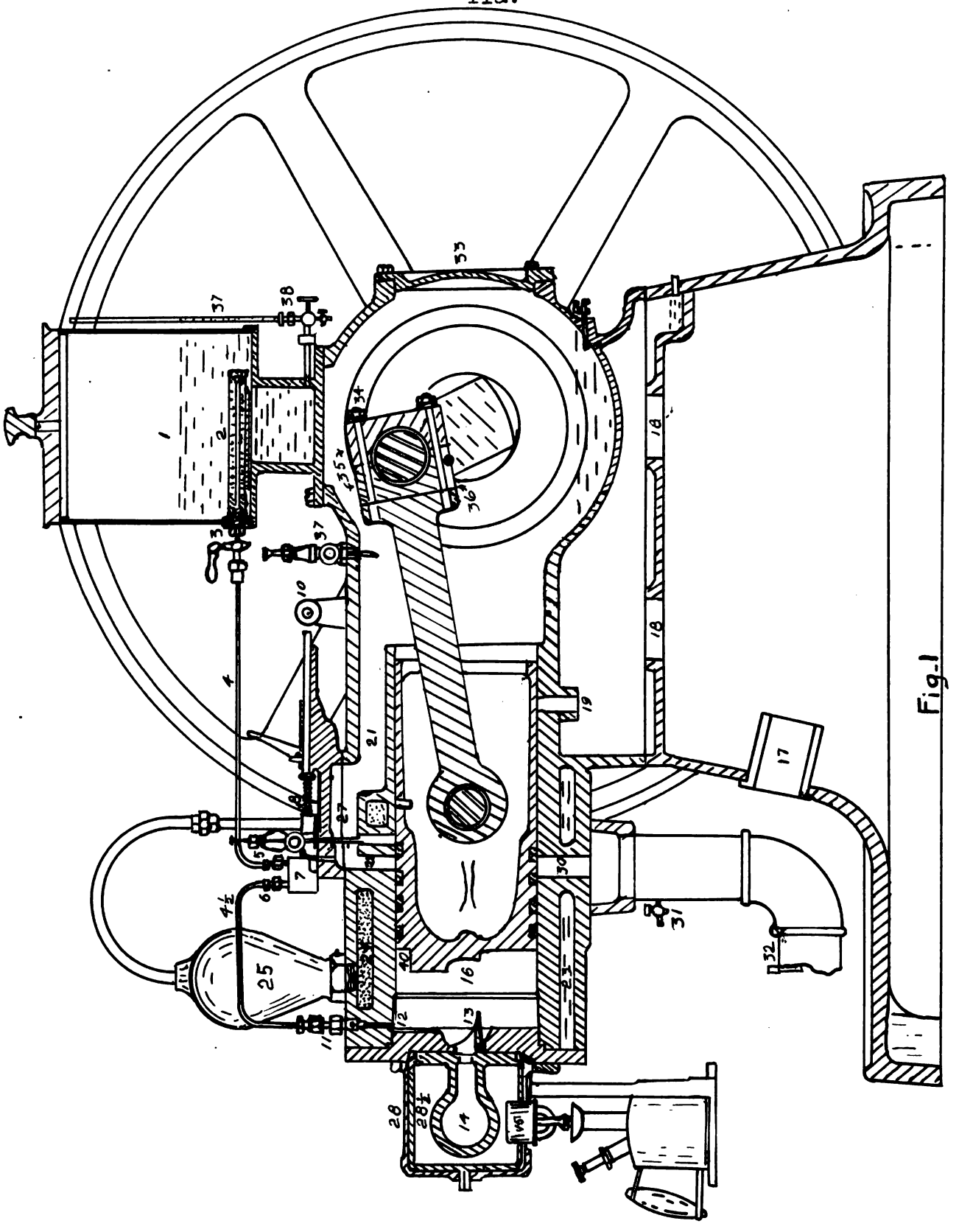


Fig.1

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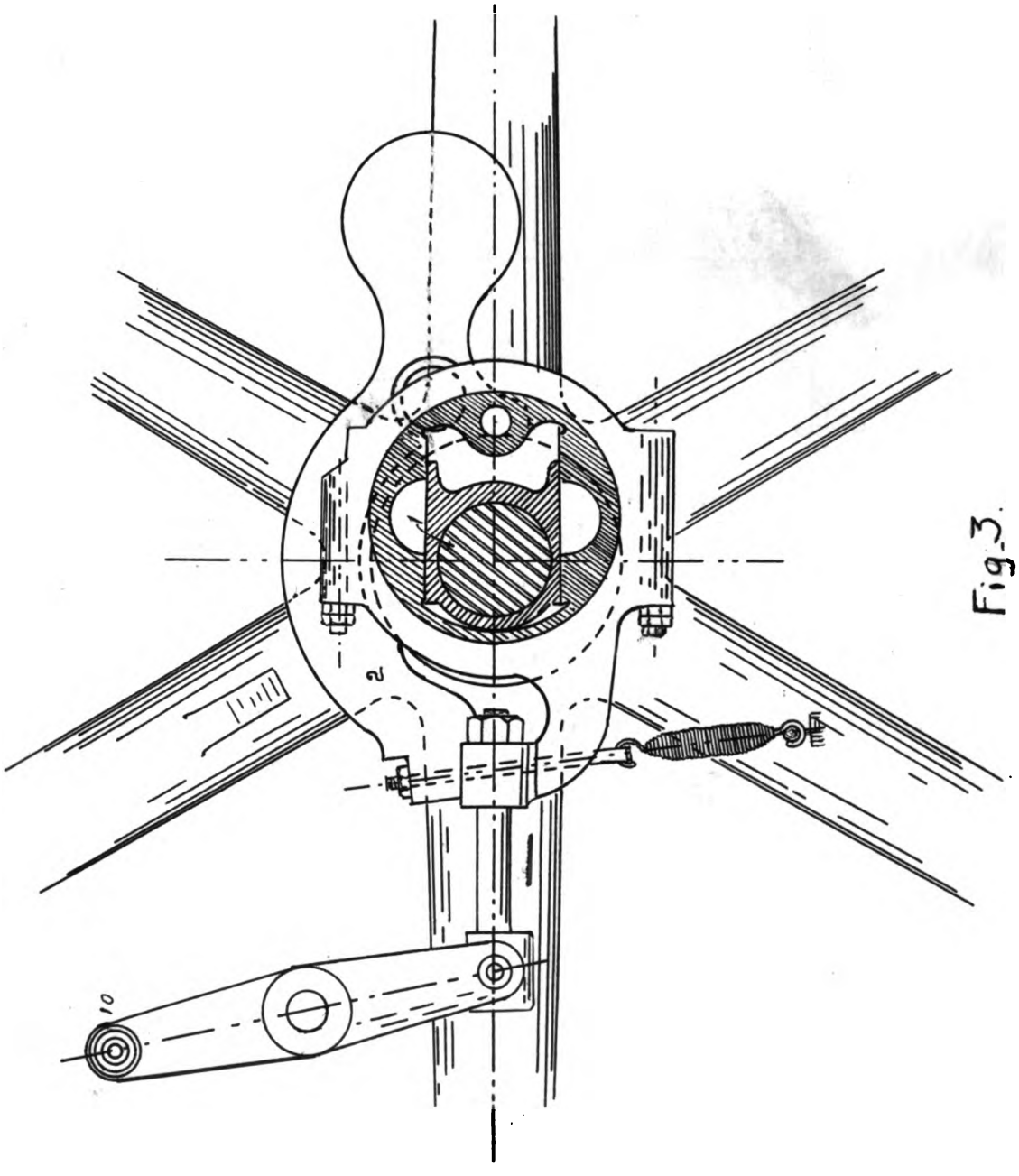


Fig 3.

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constant level by a float, 1, Fig.2 in a float box, 2.

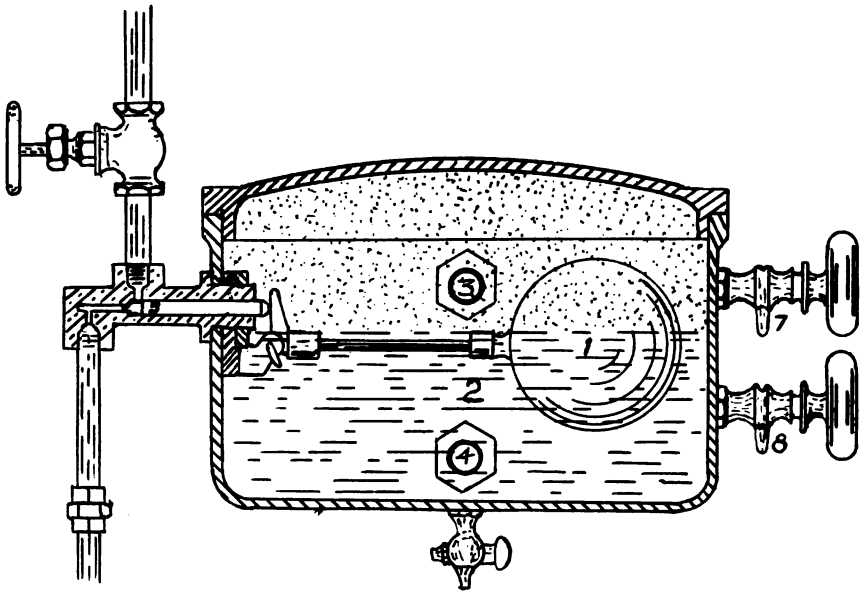


Fig-2

Two connecting nipples, 3, 4, one above the water level, the other below, join the float box with the water jacket. A needle value, 5, controls the amount of water that flows into the jacket to keep the water constant. Two cocks, 7, 8, one above the water line, the other below, show whether the water keeps a constant level.

The steam, 24 Fig.1, generated in the water jacket, passes up through the dome, 25, then on to the air port, 27, and there mixes with the air coming from the crank space. The mixture of air and steam is turned as it enters the cylinder, by a guide vane, 40, on the upper part of the piston.

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The incoming mixture being under pressure, completely sweeps the burnt gas out of the exhaust port, and leaves a thoroughly scavanged cylinder ready to receive the next charge of fuel.

The oil, used for fuel is safely stored in a copper tank, 1 Fig.1, directly over the crank chamber. Copper tubing, 4, gauge 20, connects the tank with the pump, 7, and also the pump with the combustion space, 16.

The pump is firmly bolted upon the steam and air mixing chamber cover, 41, and is of the plunger type. The oil enters the pump cylinder through a suction check, 5, and leaves it through a pressure check, 6. A double check, 11, prevents all possibility of the high pressure of the combustion space from entering the oil conductor. A nozzle tip, with a very small opening, admits the oil into the cylinder in a fine jet. The nozzle tip is directly over the lip of the igniter ball, so that the oil impinges upon the lip and is immediately atomized and vaporized.

The oil is pumped into the cylinder just after the exhaust port is closed, and since the rocker arm engages the plunger guide for only 1/12 of the stroke on full load, the time of oil introduction is comparatively short.

The vaporized oil mixes intimately with the air and

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steam, which are compressed into the clearance space. At the end of the back stroke the heat of compression has increased the temperature of the mixture enough so that by the aid of the igniter ball, the charge is ignited, and combustion occurs.

Primarily the igniter ball, 14 Fig.1, is necessary for ignition. When the engine is to be started, a lamp, 15, is placed beneath the ball and retained there until the ball is red hot. When the engine is running the lamp is removed, for the heat of the explosion keeps the ball hot.

An eccentric upon the main shaft, 1 Fig.3, causes the rocker arm, 10, to oscillate once every revolution of the shaft. Hence oil is supplied to the engine at every back stroke,- or on the two cycle plan. The angle of oscillation of the rocker arm, 10, is controlled for varying loads by a fly wheel governor, 2, Fig.3.

The engine herein described has many commendable features. First among these may be placed its extreme simplicity. It has no valves in the hot part of the engine, nor an ignitor to get out of order. Another feature is the thorough scavanging at every revolution of the crank. No burnt gas remains in the cylinder, after exhaust, to mix with the new charge.

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The method of changing the fuel supply to suit the load insures a comparatively constant speed. The speed is also kept normal because an impetus is given at every revolution.

The cooling system has a feature that has made it possible to use a heavy oil for a fuel. As before stated, all the cooling water passes through the cylinder in the form of steam. There are several reasons why such a unique method of cooling the cylinder, and disposing of the steam, is advantageous. Less water is used; no circulating pump, or other device, is required; and a more even cooling effect is obtained. The steam almost entirely prevents the deposition of carbon in the combustion space. Carbonizing is one of the inherent characteristics of an oil engine, and its prevention is a very important feature.

ARRANGEMENT AND FITTINGS.

There not being sufficient room in the Mechanical laboratory to set up the engine it was placed in the basement of the Electrical laboratory. Holes were drilled in the cement floor, bolts sunk and cemented firmly in and the engine fastened securely to the projecting studs. The exhaust pipe was run from the engine six feet to the muf-

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fler near the wall. From the muffler a four inch pipe ran upward to the window and out through a short ell.

The jacket water came through a half inch pipe from a small tank firmly attached to the joists directly above the engine. The tank was fitted with a water glass and scale, which latter was graduated to one quarter pounds.

The apparent danger attending the use of the 'Hydrocarbon' made it necessary at first to have but small quantities of it near the engine. For the purposes of a storage tank a wide mouthed bottle of about one quart capacity was attached to the top of the main storage tank. From this a glass tube led to the pump connection below, the two ends being connected through a short piece of rubber tubing. This arrangement was abandoned later and the main tank used. To the tank was attached a glass gage, 37 Fig.1, and scale, the latter being graduated to one-fourth pounds At the bottom of the gage was placed a pet cock, 38 Fig.1, for draining the tank.

A rated dynamo was used for the load. This was chosen for the following reasons:

(1) Easily changed from full load to no load or to any point between.

(2) After once rated, power easily determined and quite

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reliable.

(3) Once set, remained constant. The first proved a decided advantage as later results will show. The dynamo was rated by running as a motor and noting power required to run it at different speeds and field excitations. Wooden pulleys were made for both engine and dynamo in order to get the desired speed. The normal speed of the engine was about 400 r.p.m.; that of the generator, between 1800 and 1700 r.p.m. A bank of lamps was placed above the machine with which to load the dynamo. For the purpose of examining the exhaust gases the exhaust pipe was tapped and a pet cock, 31 Fig.1, inserted. For measuring the temperature of the exhaust gases a four inch piece of 3/8 inch gas pipe was plugged at one end and turned down for a distance of about one inch to a thin shell. Some 3/8 of an inch further was threaded and the pipe screwed into the exhaust pipe near the engine, 32 Fig.1. It was partly filled with oil and a thermometer reading to 700°F. placed within. Fig. 4 shows a sectional cut.

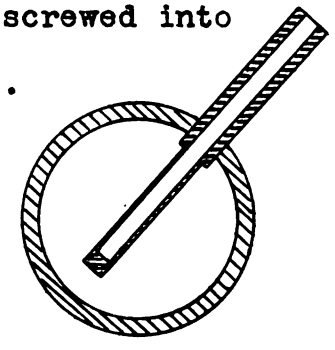


Fig-4

The engine was provided with no means of taking cards. The reducing motion used was plan-

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and designed
ned by us. Its simplicity and effectiveness deserve mention, and in the following is given a detail description of the same.

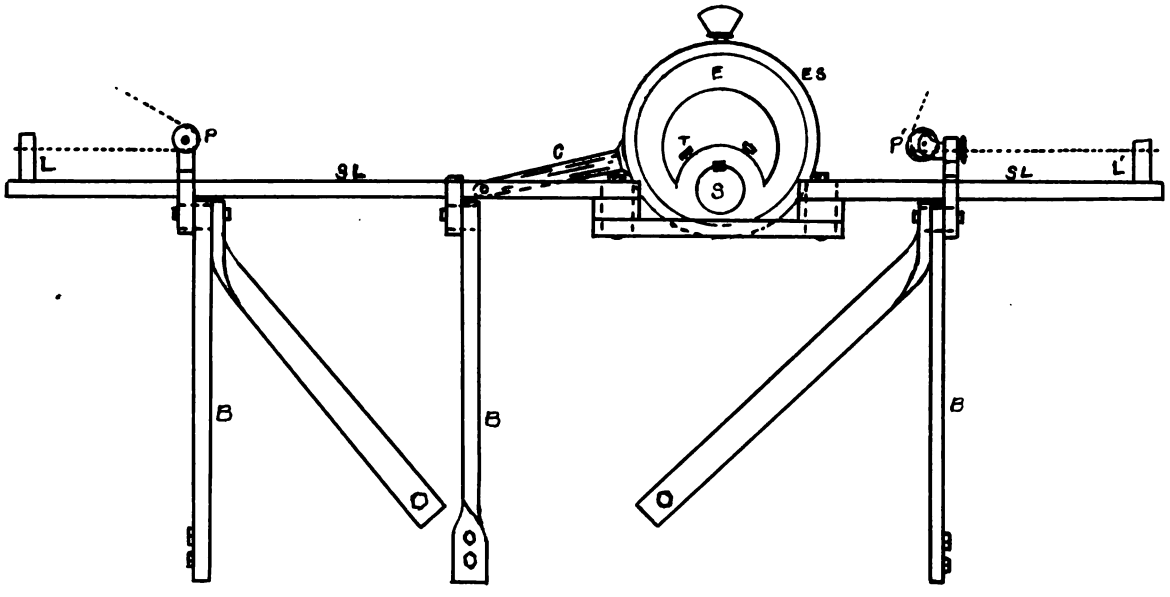


Fig-5

Reducing motion:

Length Engine connecting rod	16.00"
" " crank	3.25"
Ratio connecting rod : crank	5.00"
Desired length of card	3.00"
Corresponding throw	1.50"
Connecting rod giving above ratio	7.50"

The throw is obtained by means of an eccentric (E)

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fastened to the shaft (S) by means of two set screws (T). Provision was made for a key to fit the flywheel keyway in the shaft since this keyway was apparently intended to lie in the plane of the engine crank. Later it was found to be off about 1/32 of an inch so the set screws were used alone. The eccentric sheath (E.S.) is made of brass and held in position on the one side by a narrow flange and on the other by small clasps. The connecting rod (C) is screwed into a lug on the eccentric sheath. The slider (SL) is square and made of three pieces fastened together as shown in Fig. 5. The connecting rod is fastened to the slider in the usual manner. The latter passes through three bearings mounted upon the supports (B) which supports are rigidly fastened to the engine frame by means of cap screws. Attached to the top of the supporting brackets and lying above the slider, are the pulleys (P) and (P'). (P) is rigid while (P') is capable of revolution about an axis parallel to the slider, this axis coinciding with the string on the bottom of the pulley. Upon the ends of the slider are the slotted posts (L and L'). The heighth of the bottom of the slots is the same as the bottom of the pulleys, thus making the string from the post to the pulley parallel to the slider. It is evident that this gives the

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correct motion and it is immaterial in which direction the string leads from the pulley. Pulley (P) is made rigid since the string leading to the cylinder indicator lies directly above the slider. The crank case indicator lies to the side of the slider making it necessary that pulley (P') be movable. The indicator cord is held in the slot by a knot and being entirely separate from the moving slider, breakage is not a serious matter. To place the indicator drum in motion the string is drawn out over the slot. It is then lowered into it with the knot on the outside and released. To stop the drum the reverse process is performed. The simplicity, absolute reliability, and ease of operation of this apparatus makes it without doubt the best possible reducing motion for such an engine.

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'HYDROCARBON' IN KEROSENE OIL ENGINE.

Neither of us had had any experience with a kerosene oil engine. The carburetor and electric igniter which form the important parts of the modern gasoline engine were replaced by the injection pump and ignitor ball. While working directions accompanied the shipment and we found no difficulty in starting and operating upon normal fuel, still peculiarities were continually coming out and much time and study were spent upon these. The inherent characteristic of such an engine is peculiar to itself and, while, as before stated the object of this thesis is primary the study of 'Hydrocarbon' in an internal combustion engine, yet a great deal of time and thought was given to the study of the oil engine itself.

In the following the object will be to give a detailed description of the work as done and our reasons at that time for doing as we did. Later developments often showed our reasoning wrong but in order to arrive at the general conclusions at the end, the various steps must be given.

Our first plan was to get the engine running perfectly upon kerosene and then introduce small percentages of 'Hydro carbon', gradually increasing the amount of the latter and noting the action. First of all we desired to know just

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what the behavior of the engine would be and then, if possible, find the cause and remedy it.

Very small quantities of "Hydrocarbon' mixed with the kerosene apparently had no effect and the engine continued to run as on normal fuel. As the percentage was increased its effect became noticable in an occasional missed explosion. Cards would at times show an early ignition, but in general they were correct. A still further increase in the amount of 'Hydrocarbon' in the mixture was accompanied with more irregularity in the explosions. At times it seemed as though the engine was not receiving the correct amount of oil while again both early and late ignitions seemed to be the cause of the trouble. The indicator cards which were taken at frequent intervals were so irregular that little could be judged from them. For instance the first explosion after one or more misses could not be considered as representative of the action in the cylinder. Our experience so far led us to believe that the trouble was with the engine rather than with the oil. Hence we started the engine on kerosene alone. Its action was poor. Explosions came late and irregular and the charge was often fired in the exhaust. We stopped and made a thorough examination of the several parts. The ignitor ball was removed and examined

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for carbon deposit but seemed in perfect condition. The pump, however, worked poorly, the jet or spray injected into the cylinder, instead of being sharp and practically instantaneous, was slow and prolonged. The pump fittings were removed and the whole well cleaned. Upon being replaced the engine was again started. At first the action did not seem to be much improved. The ignitor ball did not get bright red as it had previously when the engine was in good running order. We explained this as being due to the lack of explosions and the consequent flooding of the cylinder and bulb with the unburned vapors. In order to get the bulb at the proper temperature the heating lamp was placed beneath it. The effect of this was very evident. The explosions gradually became less irregular and the cards showed ignition to take place earlier in the stroke becoming correct as the bulb reached a bright red heat. Under these conditions the engine ran very nicely for some time under full load. Without changing any other condition, 'Hydrocarbon' was added gradually until the fuel became practically all 'Hydrocarbon'. No decided change or peculiarity of action was noticeable. The engine ran thus some twenty or thirty minutes when it

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suddenly began to slow down and could not again be started.

Up to this point our experiments had been more of a general nature. We now decided to carry on a more systematic investigation. We had had experience enough thus far to tell that there were several conditions each or all of which might be causing the trouble.

The pump was again removed and the valves in the connections leading to and from the pump, examined. Valves, 11, Fig.1, in particular, were carefully inspected. It was thought that by changing the tension in the valve spring the sluggish action referred to above might be obviated. This we tried but the improvment, if any, was slight. Upon thinking the matter over it seemed very possible that the pump action was normal. At times it apparently worked perfectly. Besides its behavior under actual working conditions was apt to be very different from that as inspected with the cylinder head removed. Ignition and the ignitor ball offered an interesting field and to this we turned our attention.

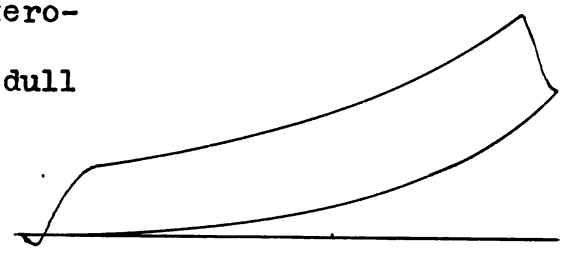
In the following we have endeavored to give the running conditions, the results, and wherever possible, a representative card. The load will be given in the number of incandescent lamps carried. No lamps represents a load of about 1.25 H.P., while the addition of one lamp represents an

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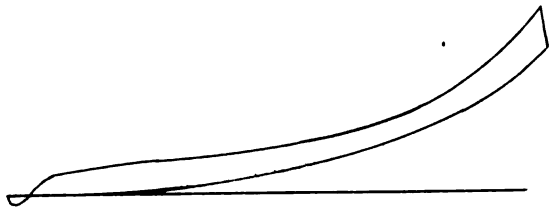
approximate increase of 1/10 H.P. From this the load on the engine at any time can be readily estimated.

The first run was made on kerosene. The bulb was heated to a dull red heat and the heater removed. The load was five lamps and the speed normal. The explosions were very irregular at first but became more regular as the bulb warmed up. The cards at first showed late ignition, but later became correct. Card No.1.



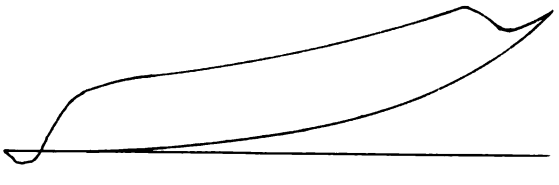
NO. 1

The belt was thrown. The speed increased rapidly and there was a tendency to miss explosions. The engine soon adjusted itself to the new conditions giving a card such as No. 2



NO. 2

With all other conditions the same a load of 11 lamps was thrown on. The engine began to slow down at once, the bulb cooled and ignition came quite late. Card No. 3.

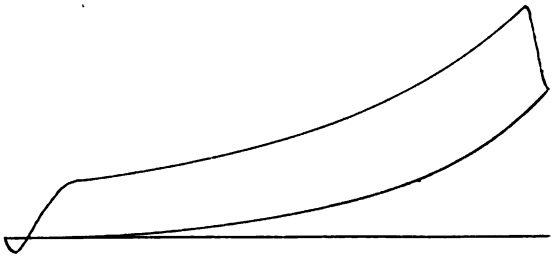


NO. 3

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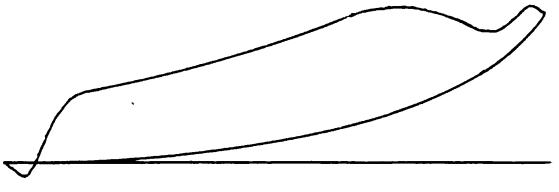
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The heater was now placed beneath the bulb and kept there continually. The latter became a very bright red and remained so. The load remained the same. The speed picked up and went slightly above normal. Ignition came at the end of the stroke. At this point the engine seemed to be running perfectly. Card No. 4.



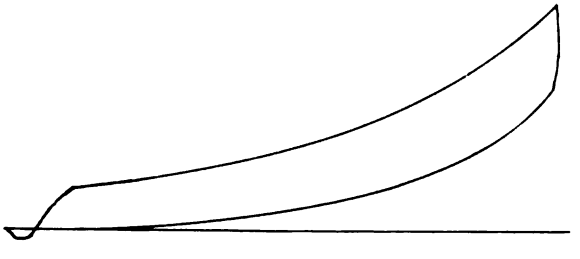
NO. 4

Six additional lamps were now added making 15 in all. The speed slowed down considerably and the engine pulled hard. The ignition came late in spite of the fact that the temperature of the bulb was very high. Card No. 5.



NO. 5

When all the lamps and field current were thrown off the engine speed went way above normal. While there was at first a slight tendency to miss explosions, it did not last and the cards showed a correct ignition. Card No. 6.

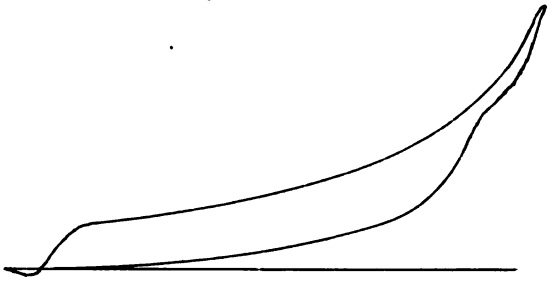


NO. 6

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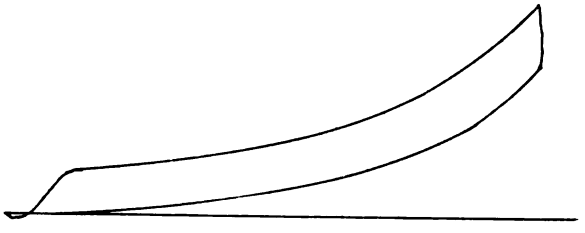
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General conclusions with kerosene as a fuel: After running upon normal load long enough to become adjusted to the conditions, the engine will run normally in all respects giving perfect cards. A rapid increase in load tends to flood the cylinder, cool the bulb, and finally stop the engine. These conclusions will be referred to and enlarged later on.



NO. 7

A series of tests were now made with the fuel a mixture of 'Hydro carbon' and kerosene at a ratio of 1 : 1. In the first case the heater was used keeping the ignitor ball at a high temperature. The load was seven lamps. At first the action was rather irregular, but improved somewhat. All at once the engine slowed down and then continued to run at this lower speed, but with regular explosions. The cards showed a preignition which partly accounts for the decrease in speed. Card No. 7.



NO. 8

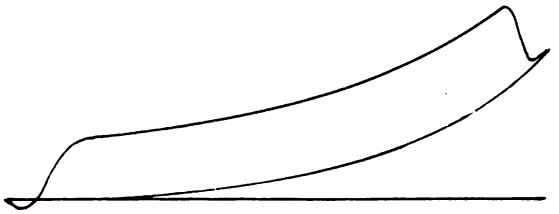
The heater was now removed and it was supposed the bulb would cool down. It did so but very slowly.

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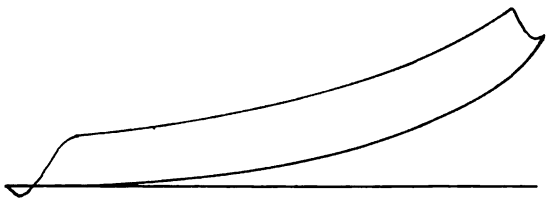
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The cards, No. 8, showed a decided improvement. After running some fifteen or twenty minutes thus the speed gradually become slower and the engine would have come to rest of its own accord had it not been stopped.

The next start was made with the engine cold. The fuel was the same as above, i.e. half and half of kerosene and 'Hydrocarbon'. The engine was started with the igniter ball a dull red and the heater allowed to remain beneath the bulb. As the latter became bright red the engine ran fairly well although ignition was a trifle late. Card No. 9. The speed, slightly low at first came up to normal. The engine ran thus for some little time occasionally missing an explosion and on the whole regulating rather poorly. The heater was then removed but with no improvement. Card No. 10.



NO. 9



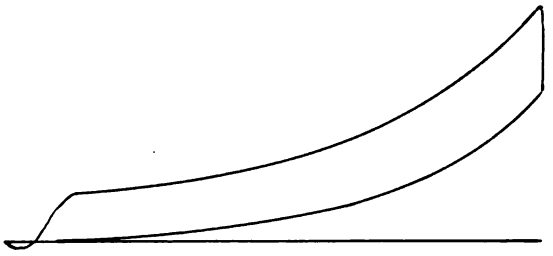
NO. 10

In order to note what effect a gradual change of load

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might have a run was made with this in mind. The engine was started with the bulb at a bright red heat and the load increased one lamp at a time. Cards



NO. 11

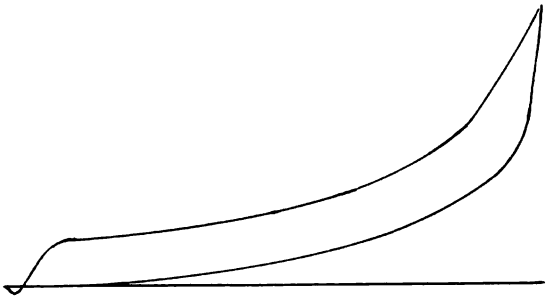
were taken with each additional lamp. These cards are not shown but they all showed ignition to take place at the end of the stroke and the explosion practically instantaneous. At the end of the sixth lamp no more load was added. The engine continued to run for some time giving a card such as No. 11. Then the explosions became late and at the same time the bulb began to cool off. As usual the engine slowed down and would have stopped of its own accord. The pump action was stopped,however, as the injections without ignitions were not only wasteful but filled the room with a suffocating odor.

As will be noted a great many of our results showed a late ignition. In order to correct this we decided to increase the compression. Two plates each 3/32 of an inch thick were made and slipped onto the bolts which hold the crank pin boxes in place. The piston would thus be sent 3/16 of an inch further towards the head end.

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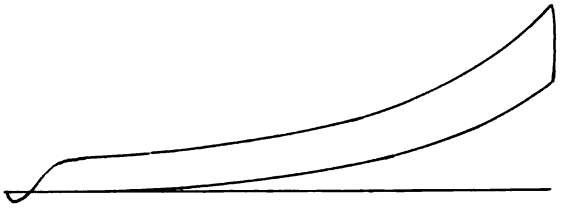
When this new adjustment had been completed an attempt was made to start the engine. In this we experienced considerable trouble but finally succeeded in getting started. For about 30 minutes it continued to run in a fairly consistent manner. The cards show ignition to come early. Card No. 12.



NO. 12

At the next trial after having once started the engine, we stopped in order to tighten the crank pin boxing. Upon trying to restart we could get no explosion and after working some little time quit for the day. We had reason to believe that no oil was being injected into the cylinder. It should be noted here that we had had this trouble in starting several times before,- that is after having once shut down. The pump was again removed and cleaned as before, but as far as we were able to see it was in perfect condition.

The 80 lb. spring in the indicator was replaced by a 120 lb. spring and another start made. The heater was used and the bulb



NO. 13

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brought to the high temperature. The resultant card, No. 13, shows correct ignition and an increase in compression of about 10 lbs. 'Hydrocarbon' was gradually added until the fuel was practically all 'Hydrocarbon'. The engine continued to run quite well. At times the ignition seemed to come late and the heater was brought into use while at other times back firing was evident. A general conclusion drawn from this test was that 'Hydrocarbon' alone did not require as much heat for ignition as the mixture did. Also that after the engine had been running for some length of time preignition was more liable to occur. We decided this latter might be due to (1) Gradual increase in temperature of cylinder as the time the engine was run increased. (2) Pump and pump connections being quite warm, thus raising temperature of liquid fuel.

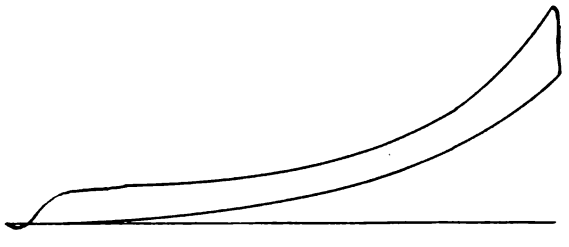
It seemed probable that when the engine had run for some time, and as its working parts began to warm up that less heat would be required in the igniter ball. As before stated the ignition came earlier as the engine continued to run. Our idea now was to gradually reduce the heat of the igniter ball as time passed thus preventing preignition. Fortunately we had a very easy and satisfactory method of doing this. When working normally with kerosene as a fuel the bulb is provided

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with a movable cover, 28-1/2 Fig.1, completely closing it from the ouside air. By opening the bulb up to the air by means of this movable cover, temperatures corresponding to a bright red to temperatures corresponding to almost a black could be obtained. With this idea in view we made another attempt.

The usual difficulty was experienced in starting with very irregular explosions. The bulb was brought up to the required heat and normal load placed upon the machine. As soon as the cards began to show preignition, the temperature of the bulb was lowered slightly. About this time the engine began to run admirably. The voltmeter showed the speed to remain practically constant. Cards were taken every 5 minutes and by noting the point of ignition the temperature of the igniter ball was regulated to suit. By this means we seemed perfectly able to control the engine. Gradually it became necessary to open the bulb up more and more to the air until finally it was entirely exposed. After running some two hours the speed began to fall off and an explosion was occasionally missed. This fault increased quite rapidly un-



NO. 14

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til finally it was necessary to stop the engine. The series of cards of which No. 14 is a fair sample were excellent. At times the ignitions were early and other times late, but in general, correct.

The results of the previcus run led us to believe we had solved one phase of the problem -- ignition. It seemed reasonable now to expect that the engine would operate better on the lower compression. The heat of compression would be reduced and by controling the temperature of the bulb, as previously described, the troubles due to premature explosions would be obviated. This we tried but were not able to get the engine started in a uniform running condition. Hence we came to no definite conclusion in regard to this change in compression. Several incidents in these later tests made us suspect the action of the pump.

This led us to turn our attention to the pump itself. On several occasions we had taken it apart, examined and cleaned the valves and replaced it seemingly in perfect condition. It was noted that the engine often ran better when first started and began to give trouble only after having run for some time. Also whenever a stop was made it was next

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to impossible to start again. An indication that oil was being injected into the cylinder was given by a flame rising above the ignitor ball upon the compression stroke. Always, upon restarting it was necessary to operate the pump by hand quite vigorously before oil would begin to flow as told by the above indication. Several times upon removing the connection between the oil tank and the pump this connecting link was found to contain no oil and to be practically dry. All these things indicated that the pump was not doing its duty.

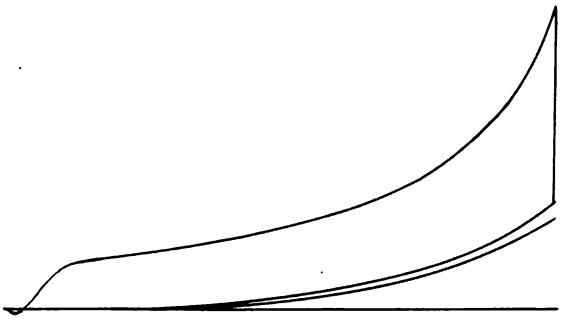
After thinking these matters over we decided to make a run with the action of the pump specifically in view. After warming the engine up by running under light load, and with the action similar to what has been described previously we allowed the engine to stop as it very often would have done did we not operate the pump by hand. A few moments after stopping we noticed that the pump was very warm, in fact so warm that the pump handle could not be operated with comfort. the connection between the tank and the pump was removed and found to be dry as expected. Then the valve next to the tank was opened. A momentary rush of gas was heard before the oil came.

We concluded from this test that the oil within the pump

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became vaporized and that the temperature of the pump must be kept low enough to prevent vaporization. In order to do this it was packed with waste which latter was kept well saturated with cold water. This was after the engine had been running for some time and was warmed up. No effect was noticeable at first but it soon became quite apparent that there was an improvement in the action. The engine worked strongly and forcibly. The bulb was gradually allowed to cool. The explosions were not regular, however, but approximately came every other revolution. As the bulb cooled to a very dull red, the engine still continued to work strongly and right up to speed. The load was 5 lamps. It should have been stated that the engine was now working on the high compression. The card, No. 15, shows one explosion and one missed explosion. The area of this card should be noted, showing that an extra quantity of oil was consumed at this explosion. It is quite evident from these results that the above explanation in regard to the pump was correct and that the remedy applied was effective.

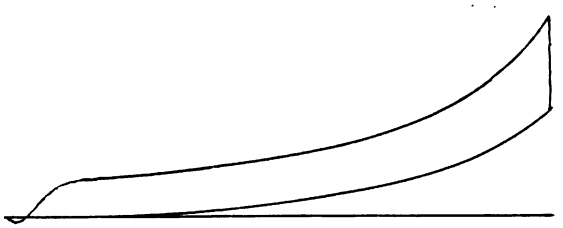


NO. 15

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In the hope of still further improving the action in stopping the irregularity of the explosions, we continued this test with a slightly different arrangement of the cooling water. A continuous stream of cold water was allowed to flow over the pump and pump fittings. This time we started with the engine cold. The improvement over anytning previous was marked. The engine missed scarcely an explosion and ran continuously up to full speed for two hours, or until it was stopped, with a few temporary slow downs. When the slow downs did occur the cards showed that not sufficient fuel was being supplied. At one time when the explosions became somewhat irregular it was noticed that the water had stopped flowing. Even with a liberal supply of water it seemed impossible to keep the pump cool enough. As is evident from the diagram of the engine, the location of the pump subjects it to considerable heat from below, and it would be necessary to insulate thoroughly from beneath to keep its temperature sufficiently low.



NO 16

Card No. 16.

Explanation:- An inspection of the sketch, Fig.1, will

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show the pump to lie directly over the cylinder and connected to it through a metal plate. The tubing, 4-1/2, is also in direct contact with the cylinder or cylinder jacket. Due to these direct connections and the fact that the temperature of the cylinder jacket is about 212°F., a considerable amount of heat is conducted to the pump and pump connection. On the suction stroke of the pump the oil within it vaporizes due both to heat and decreased pressure, and fills with vapor the space which would otherwise be occupied by the incoming oil. This may happen either in whole or in part. On the force stroke the vapor is simply compressed and hence no oil, or less oil than normal, is injected into the cylinder. The amount of oil passing into the cylinder depends on the amount of vapor present in the pump. Vapor may also form in the connection, 4-1/2, lying between the pump and the cylinder. Upon the compression stroke of the pump this vapor would be compressed. Evidently under such a condition the injection into the cylinder would be prolonged and sluggish just as was noticed to actually be the case. The injection would stop at the point where the pressure in the cylinder became equal to that in the connection and it is reasonable to believe that the flow of oil would begin again when the same pressure is reached on the expansion stroke. The mixture

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in the cylinder cannot enter the tubing at the time of high pressure on account of check valves, 11. The oil passing into the cylinder on the expansion stroke must pass out the exhaust and be wasted.

All the results show that the engine ran best when cold and only gave trouble when warmed up. If the engine was running in good shape it would continue to run thus since a continual flow of fuel would offer no great opportunities for vaporization. While on the other hand if the engine is stopped the chances for vaporation is increased since there is less opportunity to conduct the heat away from the pump.

Missed explosions can be accounted for by supposing vapor to have formed in connection, 4-1/2. Upon one forward stroke of the pump a small quantity of oil is forced into this connection and is held from returning by the check valve, 6, The vapor in the connection is compressed and the pressure within rises but not sufficient to open the valves, 11, and allow the fuel to pass into the cylinder. Upon the next stroke of the pump additional oil is forced into the connection and the increased pressure opens the valves, 11. If no vapor is formed in the pump, as we may assume was the case when the latter was kept cool, the amount injected into the cylinder each alternate revolution is double the normal

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amount.

If there is no vapor in the connection, as possibly is the case upon first starting, and the pump is kept cooled, the chance of its formation is not very great. Once having formed it will rise to be top of the tubing and is removed with difficulty.

The slowing down and gradual stopping of the engine, which so often occurred, can be attributed to the formation of vapor in the pump which cuts down the supply of fuel admitted to the cylinder. Once the vapor starts to form it continues very rapidly and the injections soon cease entirely, with the consequent stopping of the engine.

Conclusions:- In reading over the foregoing data as given, the reader is no doubt impressed with the lack of coherence in the subject matter. It must be remembered, however, that at the time these facts became known to us the explanation to them, which is really the missing link, was not available. When, at the close of our experiments we reviewed the data as taken from time to time and applied to it the simple explanation as given above we were strikingly impressed with the consistancy of our results.

Obviously it is impractical to use 'Hydrocarbon' in a kerosene oil engine of the Mietz Weiss type. The two main

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objections are: Formation of vapor in the pump and pump fittings and, difficulty of securing the correct ignition. While neither of these are beyond the possibility of control it is very probable that no satisfactory results could be obtained.

To prove whether the engine was in good working condition it was run on kerosene, the oil for which it was designed

The compression blocks were removed from the piston rod and conditions made the same as when the engine was delivered from the factory. The height of the oil in the tank was carefully marked at the beginning of each run. At the end of the run the oil was again brought to the same mark. To obtain the weight of the oil consumed, a can containing the supply of oil was weighed both before and after the tank had been replenished. The difference in the weights was the amount used for the run.

Much trouble was experienced in getting the engine to carry even a moderate load. Even when the bulb chamber was closed, the bulb would gradually cool down and the explosions come later and later, until combustion was actually at exhaust.

Two runs of 30 minutes each were made under these conditions; the first generating 1.5 D.H.P., and the second,

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1.75 D.H.P. The engine was allowed to cool and then two more runs of 30 minutes each were made. When the explosions came late the room was filled with a suffocating gas squeezed out at the head end. For the sake of experiment the blocks were replaced on the piston rod. The first most noteworthy change produced was found upon restarting the engine. In all previous runs on normal compression, and kerosene as a fuel, it was found necessary to heat the igniter ball to a red heat before attempting to start. In the instance under consideration the ball showed no signs of becoming red when the flywheel was turned over. However the engine started right off and continued to run until stopped. The lamp was removed at once, and the bulb chamber left wide open. The color of the bulb changed to a dull red, and then remained constant throughout the run. A heavy load was thrown on without materially lowering the speed. The load was increased to 15 lamps and kept at that during the half hour run that was made. A noteworthy point was the drop in the exhaust temperature in this run. The drop was doubtless due to the perfect ignition, explosions occurring at the beginning of the forward stroke with persistant regularity.

No doubt the engine was over loaded in the last run, for the speed dropped slightly throughout the test.

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After the last run several rapid changes of load were made from full load to no load, and back again. The speed changed noticeably for a time, but came back to normal as soon as the governor could adjust the oil supply to fit the new conditions. When 18 lamps were thrown in at one time the speed dropped very perceptibly, and continued to fall. The cards taken under this condition showed no increase in pressure over the 15 lamp test. It was very evident that the engine was loaded beyond its capacity. Even had enough oil been furnished to meet the increased load, the design of the cylinder would not permit enough air to support complete combustion, and hence the mixture would really have been poor for want of oxygen.

It is quite probable that the full stroke of the pump is reached when the speed is but slightly below normal. Such a condition will give a closer regulation of speed than if the range were wide.

The engine, to be properly designed, must necessarily have a proper mixture of oil and air when it is taxed to its rated load. Below full load the mixture will then be poor in fuel, and above full load it will either be poor in oxygen, or have to fail to do the required work for want of thermal units.

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In case of an engine with a bulb igniter it should obtain that the ball would become the hottest during full load, because under that condition there is complete combustion. When the load decreases the fuel also decreases, and the temperature of combustion, and consequently the temperature of the ball, drops. Should there be an over load, with the possibility of a corresponding increase in oil, much of the oil,-- the surplus-- could not be burned. All the heat required to vaporize the surplus oil would be taken out of the igniter ball, lessening the chance for ignition of the charge. And then, since the surplus could not be burned, the heat required for vaporization would not be returned to the igniter, and the chances for vaporizing the next charge would be lessened. A condition would be reached where there would be neither vaporization nor ignition because the temperature of the ball had been reduced below that critical point. The result would be that the oil would flood the cylinder, and the engine would stop.

It is evident that it is not only useless, but actually detrimental to furnish more oil than is required by a full load.

The numerous experiments, made on varying loads of wide range, proved conslusively that the bulb becomes and remains

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the hottest under one load:- that load being the normal for the engine. Both above and below that load the bulb cools very perceptibly, for reasons given above.

TEST WITH KEROSENE.

Test No.	Currents		Speed		Eng. Out Put		
	Volts	Load	Field	Dynamo	Engine	Watts	H.P.
1	117.3	1.855	1.402	1819	429.2	1153	1.511
2	112.6	3.53	1.413	1752	413.0	1330	1.788
3	101.3	4.56	1.376	1596	377.0	1107	1.75
4	97.	6.09	1.395	1550	365.5	1432	1.92

Test No.	M. E. P.			I.H.P.	Temperature °F		Eff.
	Head	Crank	Effec.		Water	Exhaust	Mech.
1	22.6	1.74	20.85	2.33	64	376	64.8
2	24.67	1.68	22.83	2.466	64	415	72.6
3	26.	1.68	24.3	2.39	63	414	73.2
4	27.1	1.67	25.4	2.43	63	395	79.0

Test No.	Pounds oil used			Pounds Water Used.		
	Total	Per D.H.P. hr.	Per I.H.P. hr.	Total	Per D.H.P. hr.	Per I.H.P. hr.
1	1.531	2.025	1.315	1.875	2.48	1.61
2	2.1	2.1	1.46	3.47	4.31	2.81
3	1.375	1.57	1.15	2.094	2.3	1.75
4	1.5	1.562	1.235	2.625	2.73	2.13

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'HYDROCARBON' IN AN ENGINE FITTED WITH CARBURETOR.

After experimenting and handling the oil, and noting its extreme volatility, it seemed plausible to think it might be used in a carburetor. Through the kindness of Messrs. Wagle and McMullen we were permitted to use a gasoline engine completely fitted up by them for testing.

The engine was rated at 3-1/2 H.P. and is manufactured by the Baker Co. of Evansville, Wis. The carburetor is of the simple needle valve construction. The oil tank lies below the level of the valve, and the feed pipe is fitted with a check valve. On the suction stroke of the engine the spray of oil is forced into the air inlet pipe from which the charge passes to the cylinder. A thumb screw fitted with notches controls the needle valve and thus the mixture. A simple friction brake was used for the load.

Our object here might be said to have consisted in three things, the latter two of which depended upon the first which was of chief importance. These were:

1. Would the engine as fitted for gasoline run with 'Hydrocarbon' as a fuel.

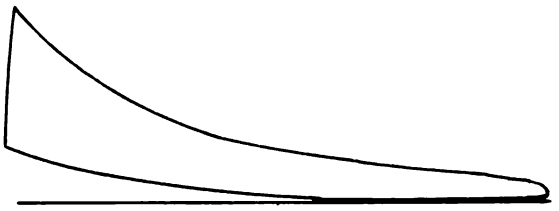
2. Under what loads would it operate successfully.

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3. What mixtures would give the best results.

The tank was filled with 'Hydrocarbon' and the engine 'cranked'. It started and apparently ran just as well as with gasoline. The cards showed up favorably as compared with the normal cards from the engine. Card No. 17. Since the engine was governed by the 'hit and miss' method, the number of explosions missed upon light loads was considerable.



NO 17

The first explosion coming after a miss gave a peculiar card as shown in No. 18. The cause of this was not definitely known but was thought to be due to the water injected into the exhaust to cool the latter. At any rate it is immaterial since exactly the same results were had when gasoline was used, showing it to be the fault of the engine and not the oil. The M.E.P. in the two cases is about the same.



NO. 18

Knowing that the oil would burn we next proceeded to

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make a series of tests. The first three runs were made with increasing loads. In Test No. 3 the engine was apparently loaded to its maximum capacity. As no easy method was at hand for determining the exact mixtures comparison was made between different mixtures by noting the notch at which the needle valve was placed. The position is noted in the data for the different tests. The latter four tests were made with the object of determining the best mixture for a constant load. Analyses of the exhaust gases were made in all but the first two tests to aid in making comparisons. The data in connection with gasoline are taken from the tests of Messrs. Wagle and McMullen and are added for comparison.

'HYDROCARBON'

Test No.	Rev/Min.	Exp/Min.	I.H.P.	D.H.P.	Mech. Eff.
1	399.6	107.8	2.74	1.68	61.3
2	395.4	161.3	3.60	2.52	70.0
3	396.0	176.3	3.90	2.96	76.0
4	399.6	129.1	2.72	1.24	45.5
5	400.3	110.4	2.41	1.25	51.8
6	401.6	94.2	2.16	1.25	57.8
7	400.3	91.8	2.17	1.25	57.5

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'HYDROCARBON'

Test No.	Oil Used per D.H.P.hr.	per I.H.P.hr.	Heat Sup,/ I.H.P.hr.	Thermal Eff. %	Needle valve notch
1	1.36	.832	17200	14.8	5
2	.91	.636	13130	19.4	4
3	.95	.720	14862	17.2	4
4	1.44	.657	13600	18.7	3
5	1.28	.663	13700	18.55	3.5
6	1.26	.732	15150	16.8	4.0
7	1.305	.776	16030	15.7	4.5

GASOLINE.

Test No.	I.H.P.	D.H.P.	Mech. Eff.	Oil/ D.H.P.hr.	Heat Sup/ I.H.P.hr	Therm. Eff.	Valve notch.
1	2.2	1.32	69	1.33	18900	13.5	
2	3.86	2.87	74	.91	13900	18.4	
3	3.62	3.07	85	1.48	15400	16.6	4.5
4	1.65	.93	56	1.38	15900	16.0	5.0

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EXHAUST GAS ANALYSES.

Test No.	'Hydrocarbon' CO_2	'Hydrocarbon' CO	'Hydrocarbon' O	Gasoline CO_2	Gasoline CO	Gasoline O
1				7.8	9.1	2.6
2				11.5	1.0	1.0
3	10.5	1.1	1.3	10.0	.8	3.0
4	9.6	0	5.4	---	---	---
5	10.1	0	5.3			
6	11.6	.4	2.0			
7	9.8	1.2	2.8			

An inspection of these results will show several facts, although they are not consistant in all respects. Test No. 2 shows exceedingly good results with the engine running under normal load. In test No. 1 too much oil was used evidently. Test No. 3 shows up nearly as well as test No. 2. It should be noticed that the amount of 'Hydrocarbon' used per D.H.P. compares very favorably with the gasoline and seemingly has a slight advantage over it. The thermal efficiencies are also excellent, especially on the better mixtures. The last four tests, made with a constant load, and with a view of determining the best mixture, are not as satisfactory as they would have been with a load more nearly normal.

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However they serve for comparison. Of these, test No. 6 probably shows the best results. The needle valve notch was at 4 which will be noticed is the same as in tests Nos. 2 and 3. The exhaust gas also shows up well here. Assuming that we have 85% nitrogen the probable percent of combustible present in the exhaust gas is small.

The conclusions that may be drawn from these tests are:

1 'Hydrocarbon' may be used in an internal combustion engine having a carburetor similar to that of a gasoline engine.

2. Its efficiency as so used is as high and probably somewhat higher than gasoline.

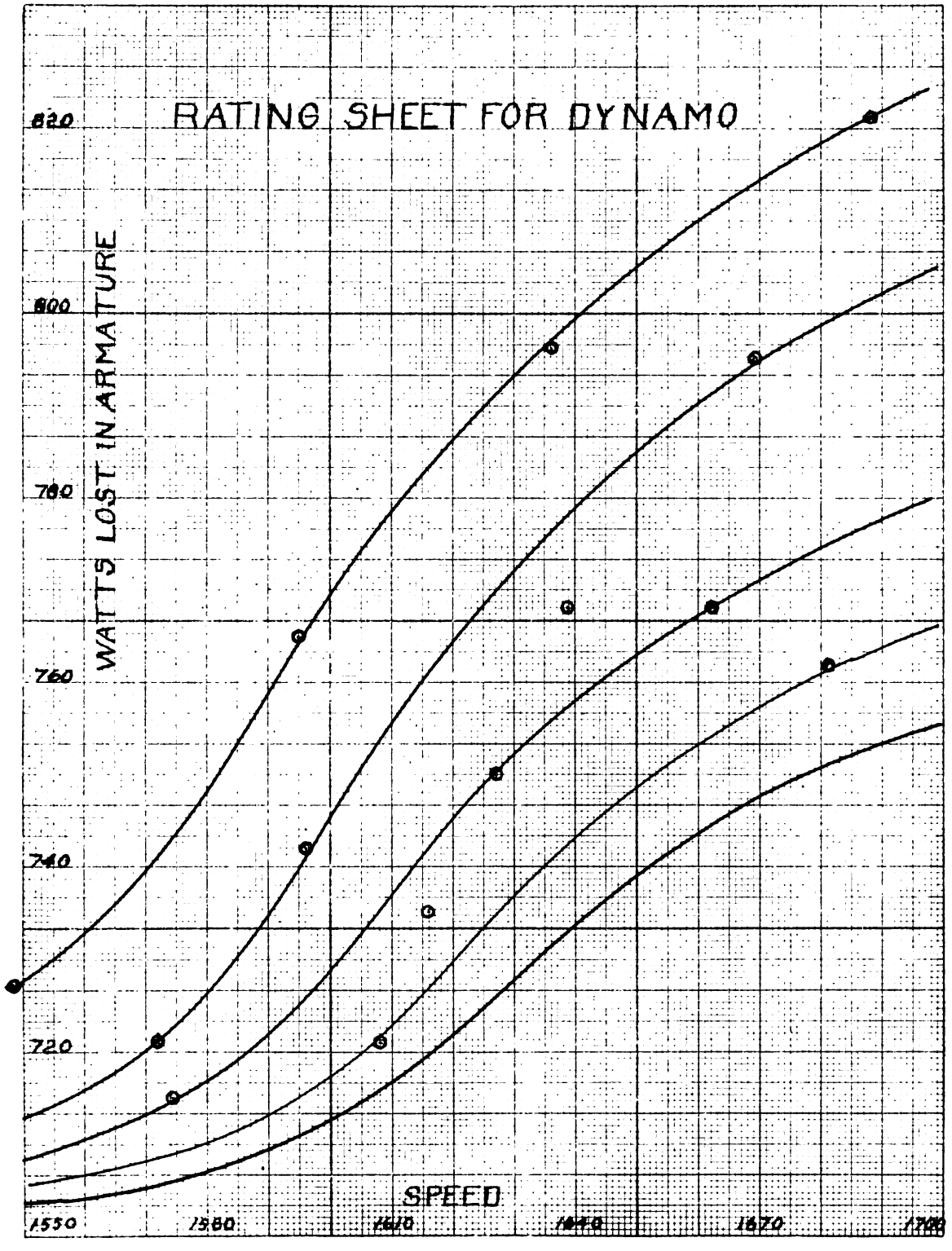
3. Apparently there are no mechanical or other objections to its use.

In the foregoing no great attempt was made at accuracy. Such was not our immediate object. It is evident here that the results arrived at are very satisfactory.

General Conclusions: There need be little said here. At the close of the various parts of this work we have endeavored to sum up the points considered and the conclusions drawn. The remainder we leave to the reader.

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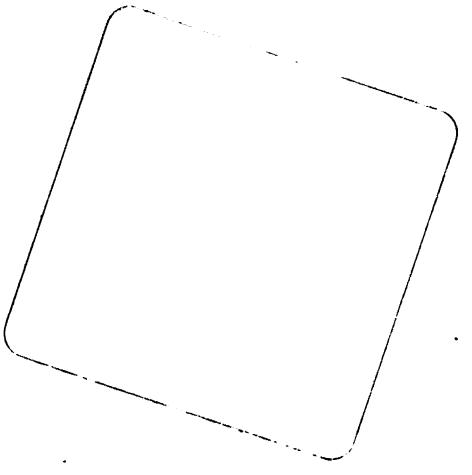
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